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Guidance Manual: Cost Estimates for
Closure and Post-Closure Plans
(Subparts G and H). Volume 4. Documentation

Pope-Reid Associates, Inc., St. Paul, MN

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FINAL REPORT

GUIDANCE MANUAL: COST ESTIMATES
FOR CLOSURE AND POST-CLOSURE PLANS
(SUBPARTS G AND H)

VOLUME IV - DOCUMENTATION

Prepared for:

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CHAPTER 1

1.1 INTRODUCTION

This is Volume IV of the Guidance Manual: Cost Estimates for Closure and Post-Closure Plans (Subparts G and H). It contains the documentation for the unit costs presented in Volume III. The purpose of this documentation is to:

- present information on the source(s) used for each unit cost;
- provide examples of any computations performed in developing a unit cost; and
- describe any assumptions made in developing the unit costs.

All costs are in 1986 dollars. They were developed based on the regulatory requirement that closure and post-closure cost estimates reflect the costs of a third party performing all closure/post-closure activities.

Following this introduction, Volume IV is divided into nine chapters that correspond to the unit cost chapters in Volume III. These chapters are:

- Monitoring and Testing
- Inspection and Maintenance
- Inventory and Residual Management
- Equipment and Facility Decontamination
- Demolition and Excavation
- Final Cover and Revegetation
- Certification of Closure and Post-Closure
- Labor Categories and Rates
- Closure and Post-Closure Indirect Costs

CHAPTER 2
MONITORING AND TESTING

2.1 GROUNDWATER MONITORING

2.1.2 Groundwater Quality Analysis

<u>Parameter</u>	<u>Lab #1</u>	<u>Lab #2</u>	<u>Lab #3</u>	<u>Average Cost</u>
chlorides	\$13.00	\$11.00	\$ 7.50	\$10.50
iron	10.50	14.00	11.00	11.83
manganese	10.50	14.00	11.00	11.83
phenols (total)	33.00	39.00	14.00	28.67
sodium	10.50	14.00	11.00	11.83
sulfate	16.00	11.00	8.00	11.67
Total	\$93.50	\$103.00	\$62.50	\$86.33

Typical groundwater quality unit cost/well = \$86.00

2.1.2 Groundwater Contamination Analysis

<u>Parameter</u>	<u>Lab #1</u>	<u>Lab #2</u>	<u>Lab #3</u>	<u>Average Cost</u>
pH	\$ 4.00	\$ 4.00	\$ 5.50	\$ 4.50
specific conductance	6.50	9.00	8.00	7.83
total organic carbon	45.00	100.00	26.50	35.75 ⁽¹⁾
total organic halogen	55.00		90.00	72.50 ⁽²⁾
Total	\$110.50	\$113.00	\$130.00	\$120.58

Typical groundwater contamination analysis unit cost/well = \$121.00

(1) Total organic carbon average cost = $\$45.00 + 26.50/2 = \$35.75$

(2) Total organic halogen average cost = $\$55.00 + 90.00/2 = \$72.50$

2.1.3 Primary Drinking Water Parameters Analysis

<u>Parameters</u>	<u>Lab #1</u>	<u>Lab #2</u>	<u>Lab #3</u>	<u>Lab #4</u>	<u>Lab #5</u>	<u>Lab #7</u>	<u>Average Cost</u>
arsenic		\$ 17		\$ 35	\$ 18	\$ 21	\$ 23
barium						16	16
cadmium		14		12	9	12	12
chromium		14		12	9	12	12
lead		14					
mercury		34		30	25	26	29
selenium						21	21
silver						12	12
pesticides (Endrin, Lindane, Methoxychlor, & Toxaphene)		125				100	113
herbicides (2,4-D and 2,4, 5-TP Silvex)		125				125	125
radium (226 and 228)	\$ 85	205	\$ 66				
gross alpha		55		215			182
gross beta	22	55	26				
turbidity	8	9	7	12			9
coliform bacteria	14	25	11	18			17
Total							\$583

2.1.4 Detection Monitoring or Compliance Monitoring

• Cost Summary

<u>Method/Constituents</u>	<u>Analysis Cost (\$)</u>					
	<u>A(1)</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E(10)</u>	<u>F</u>
1. Inductively coupled plasma (Metals)	76- 152 (2)	290- 355 (3)	85- 100	125	202 (11)	--
2. AA (Mercury, cold vapor)	15- 30	Incl. with #1	37	25	30	--
3. AA (Osmium, graphite furnace)	15- 20	Incl. with #1	40	50	--	--
4. GC (PCBs & pesticides)	150- 175	525- 635 (4)	100- 200	200	90	--
5. GC (Organophosphorus pesticides)	--	Incl. with #4	125- 150	235	--	--
6. GC (Chlorinated herbicides)	--	Incl. with #4	130- 200	--	120	120 (12)
7. GC/MS (Volatile organics)	240- 255	311- 416	250- 500	300	125	100 (13)
8. GC/MS (Semivolatile organics, capillary)	1340- 1560	994- 1249	650- 1200	400	--	--
9. HPLC (Phenols)	200- 300 (5)	560- 680 (5)	175- 400	225 (6)	222	150 (14)
10. HPLC (Thioureas)	Incl. with #9	Incl. with #9	175- 400	--	--	--

<u>Method/Constituents</u>	<u>Analysis Cost (\$)</u>					
	<u>A(1)</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E(10)</u>	<u>F</u>
11. Cyanides, total and amenable	90- 110	30- 45	45	50	40	--
12. Sulfides	15- 20	Incl. 12 with #11	12	17.50	--	--
13. GC (Phthalate esters)	--	--	--	175	300	--
14. GC (Polynuclear aromatics)	--	--	--	200	150	140 (15)
15. GC (Acrolein, acrylonitrile, acetonitrile)	--	--	--	165	--	--
16. Method 611 (Halo ethers)	--	--	--	--	200	--
17. Method 612 (Chlorinated hydro- carbons)	--	--	--	--	200	--
Total Cost	\$2141- 2622	2710- 3380 (7)	1824- 3384 (8)	2343 (9)	1677	510 (16)
Number of Appendix VIII Constituents	310	317	300	322	157	85

-- = no data

• Notes for Cost Summary

- (1) Lower end of cost range is for 1-5 samples; higher end is for >5 samples.
- (2) For 19 metals.
- (3) Given as total cost for metals.
- (4) Given as total cost for GC analyses.

- (5) Given as total cost for HPLC analyses.
- (6) Given for analysis by GC, not HPLC.
- (7) 5-15% discount for >10 samples.
- (8) 10-15% discount for 5-2 (?) samples.
- (9) 15% discount for >10 samples.
- (10) Some assumptions have been made with regard to method (i.e., GC, GC/MS, etc.).
- (11) For 16 metals plus other inorganics.
- (12) Called "chlorinated pesticides"; can do 25.
- (13) Can analyze for 33.
- (14) Can analyze for 11.
- (15) Can analyze for 16.
- (16) 5% discount for >10 samples.

● Sources:

A-D - ICF, Inc. and Geraghty & Miller, Inc., Economic Analysis of a Proposal to Modify Groundwater Monitoring Requirements, draft report, September, 1983.

E - Lab #4

F - Lab #3

Discussions with EPA Office of Solid Waste staff; 202-382-2791.

2.2 SOIL MONITORING

2.2.1 Soil Core Monitoring

Parameter	Lab #5	Lab #6	Lab #4	Lab #2	Lab #7	Lab #3
sample	\$ 12	\$ -	\$ 35	\$ 20		
preparation						
cadmium	9	*	12	14		
arsenic	18	40	35	17		
lead	9	*	12	14		
mercury	25	40	30	34		
chromium	9	*	12	14		
zinc	9	*	12	14		
copper	9	*	12	14		
selenium					\$ 21	
barium					16	
cyanide				39		
sulfide				75		
pH				4		\$ 5.50
total nitrogen	20	25	30	27.50		
total solids	8	15	12	9		
organic matter	8	20	9	20		
pesticides				125	100	
(Endrin, Lindane, Methoxychlor, and Toxaphene)						
herbicides				125	125	
(2,4-D and 2,4, 5-TP Silvex)						

* For these metals the cost is \$30.00 for the first metal plus \$10.00 each for additional metals.

2.2.2 Soil-Pore Liquid Monitoring

Parameter

pH
specific conductance
total organic carbon
total organic halogen

See Groundwater Contamination Analysis Section

<u>Parameter</u>	<u>Lab #7</u>	<u>Lab #2</u>
arsenic	\$ 21	
barium	16	
cadmium	12	
chromium	12	
lead	12	
mercury	26	
selenium	21	
silver	12	
pesticides (Endrin, Lindane, Methoxy- chlor, and Toxaphene)	100	\$ 125
herbicides (2,4-D and 2,4,5-TP Silvex)	125	125

2.3 TESTING FOR SOIL CONTAMINATION

Same assumptions as soil analysis. See the Soil Core Monitoring Section.

2.4 AIR QUALITY MONITORING

- Volatile Organic Sampling Train (VOST)

\$50,000 to \$75,000

- Modified Method V Analysis for volatiles and semi-volatiles

\$20,000 to \$50,000

Source: Midwest Research Institute, Kansas City, Missouri,
816-753-7600, October, 1986.

CHAPTER 3
INSPECTION AND MAINTENANCE

3.1 CLOSURE AND POST-CLOSURE INSPECTION AND MAINTENANCE

3.1.1 Leachate Collection System Maintenance

Pump Replacement

- Pump cost
- Assuming bronze pump, automatic, 10-ft head
 - 22 GPM, 1/4 HP, 1-1/4" discharge \$265.00
 - 68 GPM, 1/2 HP, 1-1/4" or 1-1/2" discharge \$400.00
 - 94 GPM, 1/2 HP, 1-1/4" or 1-1/2" discharge \$535.00
 - 105 GPM, 1/2 HP, 2" or 3" discharge \$525.00

Source: R.S. Means, Means Site Work Cost Data 1986, p. 211.

Leachate Collection System High-Pressure Cleaning

- Equipment Rental Cost
 - \$236/wk + 10% subcontractor's profit =
 - \$260/wk ÷ 40 hrs/wk = \$6.50/hr
- Equipment Operating Cost
 - \$5.32/hr + 10% subcontractor's profit =
 - \$5.85/hr

Source: R. S. Means, Means Site Work Cost Data 1986, p. 14.

- Labor
 - \$23/hr
- Total Unit Cost
 - \$35.35/hr

3.1.2 Groundwater Monitoring Well Construction or Replacement

- Casing and screen

2 inch diameter stainless steel casing, includes fittings	\$ 9/ft
10 foot screen, 2 inch diameter	\$290/each
5 foot screen, 1 inch diameter	\$160/each

Source: Vendor X; March 1986

- Pump, tubing, and cap

teflon bladder pump	\$495/each
teflon lined tubing	\$2.75/ft
well cap	\$ 70/each

Source: Vendor W; July 1986

- Installation

drilling and installation, includes sampling and testing	\$ 22/ft
--	----------

Source: Vendor Y; March 1986

- Mobilization/demobilization

\$1.50/mile

PRA has assumed 100 miles round trip as a typical distance.

$\$1.50/\text{mile} \times 100 \text{ miles} = \$150$

Source: Vendor AA, October 1986

- Sealing

Grout from bottom of well up	\$3/ft
------------------------------	--------

Source: Vendor AA, October 1986

3.1.3 Lysimeter Maintenance

- Travel to/from site

\$85/hr for all travel costs for technician to travel to and from site

Source: Lab #8; October, 1985 and PRA engineering judgement.

- Preparation/installation of lysimeter
 - 2-3 hours for preparation of lysimeter
 - 0.5-1 hour for installation of replacement lysimeter
 - Use 4 hours - technician at \$20.50/hr
 - Labor cost = (4 hours)(\$20.50/hr) = \$82.00
 - Source: Lab #8; October, 1985 and PRA engineering judgement.
- Lysimeter
 - \$50.00 per lysimeter
 - Source: Vendor B; October, 1985.
- Total Cost
 - labor and lysimeter = cost/lysimeter
 - \$82.00 + \$50.00 = \$132.00

3.1.4 Security System Maintenance and Repair

- Fencing (with barbed wire)
 - Range: 9 ga. wire, galvanized steel = \$7.55/L.F.
 - 6 ga. wire, aluminized steel = \$11.95/L.F.
 - Typical: 6 ga. wire, galvanized steel = \$10.55/L.F.
 - Source: R.S. Means, Means Site Work Cost Data 1986, p. 92.
- Fencing (no barbed wire)
 - Range: 6 ga. wire, galvanized steel = \$10.10/L.F.
 - 6 ga. wire, aluminized steel = \$11.55/L.F.
 - Typical: 6 ga. wire, galvanized steel = \$10.10/L.F.
 - Source: R.S. Means, Means Site Work Cost Data 1986, p. 92.
- Gate
 - Range: 6' high fence, 1-5/8" frame, 3' wide, galv. steel = \$80/gate
 - 6' high fence, 1-5/8" frame, 3' wide, aluminized steel = \$93/gate
 - Source: R.S. Means, Means Site Work Cost Data 1986, p. 92.

- Corner Posts

Range: 3" diameter, galvanized steel = \$57/post
3" diameter, aluminized steel = \$67/post

Typical: galvanized steel post = \$57/post

Source: R.S. Means, Means Site Work Cost Data 1986, p. 92.

- Barbed Wire

Range: Imported, steel, galvanized, 15-1/2 ga. = \$28/1000 L.F.
Aluminum barbed wire, 12-1/2 ga. = \$110/1000 L.F.

Typical: galvanized steel 15-1/2 ga. barbed wire = \$28/1000 L.F.

Source: R.S. Means, Means Site Work Cost Data 1986, p. 155.

- Helical Fence Topping

Range: Galvanized steel, 15-1/2 ga., 18 inch coil = \$99.00/100 L.F. to
\$121.00/100 L.F.

Typical: Galvanized steel, 15-1/2 ga., 18 inch coil = \$110.00/L.F.

Price was derived through vendor contacts. Range of costs was calculated assuming ten percent on either side of the mean for regional differences in materials costs.

Source: Vendor F; March 18, 1986.

- Signs

Range: Miscellaneous directional signs, 12" x 18", reflectorized =
\$21/sign

24" x 24", stock signs, high intensity = \$48/sign

Typical: 12" x 18" reflectorized = \$21/sign

steel sign post, galvanized, 10' upright bolted = \$29/post

steel sign post, galvanized, 12' upright bolted = \$34/post

Source: R.S. Means, Means Site Work Cost Data 1986, p. 90.

3.1.5 Wind Dispersal Structure Inspection and Repair

Blue Spruce Replacement

- 7 ft - 8 ft blue spruce tree = \$100/tree

Source: Vendor BB; October, 1985.

- Delivery, labor, and equipment

2 laborers	= \$ 368.80/day
1 equipment operator	= \$ 225.60/day
1 backhoe, 48 H.P.	= \$ 171.60/day
1 truck driver	= \$ 190.40/day
1 dump truck	= \$ 242.20/day
	<u>\$1198.60/day</u>

Output = 30 trees/day

Cost = \$1198.60/30 = \$40/tree

Source: R. S. Means, Means Site Work Cost Data 1986, p. 107.

- Unit Cost

\$100/tree + \$40/tree = \$140/tree

Polypropylene Screen

- Polypropylene silt fence = \$2.76/ft

Source: R.S. Means, Means Site Work Cost Data 1986, p. 101.

3.1.6 Surveying and Maintenance of Waste Management Area Boundaries

- Steel post, galvanized, 10' upright = \$29.00

Source: R.S. Means, Means Site Work Cost Data 1986, p. 90.

3.2 POST-CLOSURE INSPECTION AND MAINTENANCE

3.2.1 Mowing and Sprinkling

Mowing

- Information Obtained:

Minnesota Department of Transportation:

mowing strips along road with large, 3-bar tractor mower

approximately 2 acres/hr

Landscape Maintenance:

using tractor mower 18'10" bars; gets within 6" of fence

10 acres in 2 to 3 hrs or 3 to 5 acres/hr

\$65/hr for tractor mower and labor;
assumes 1 hr travel time

Seasonal Lawn Care:

\$35/acre and 3 acres/hr

- Range:

2 to 5 acres per hr

\$13 to \$35 per acre

- Typical:

3 acres per hr

\$25 per acre

Source: MN Dept. of Transportation, St. Paul, MN, 612-779-1159;
August, 1985.
Vendor C; March, 1986.
Vendor D; March, 1986.

Sprinkling

- Calculation:

(crew equipment cost/day) x (profit) + 3rd party labor cost/day

- Watertank, engine driven discharge, 5000 gallons

$(\$214.20/\text{day} \times 1.1) + (\$23.00/\text{hr} \times 8 \text{ hr}/\text{day}) = \$419.62/\text{day}$

(round to \$420/day)

Source: R.S. Means, Means Site Work Cost Data 1986, p. 17.

3.2.2 Fertilizing

- 0.2 lb/yd², tractor spreader = \$4.03/1000 ft²

$$\$4.03/1000 \text{ ft}^2 \times \frac{43,560 \text{ ft}^2/\text{acre}}{1000 \text{ ft}^2} = \$175.55/\text{acre}$$

(round to \$176.00/acre)

- Equipment mobilization/demobilization = \$105.00

Source: R.S. Means, Means Site Work Cost Data 1986, pp. 103 and 41.

3.2.3 Re-establishment of Vegetative Cover and Other Cover Repairs

- Calculation for Seeding

$$\begin{aligned} & [(\text{seed cost}/1000 \text{ ft}^2 \times 10\% \text{ O\&P}) + (\text{labor rate}/1000 \text{ ft}^2 \times \\ & 44.1\% \text{ labor overhead}) + (\text{equipment cost}/1000 \text{ ft}^2 \times 10\% \text{ O\&P})] \\ & \times \frac{43,560 \text{ ft}^2/\text{acre}}{1000 \text{ ft}^2} = \text{seeding cost/acre} \end{aligned}$$

- Seeding for Repair of Routine Erosion Damage, Repair of Drainage Channels

Slope mix, 6 lb/1000 ft²; push spreader used because area will probably be small

$$(6 \text{ lb}/1000 \text{ ft}^2) \times \frac{43,560 \text{ ft}^2/\text{acre}}{1000 \text{ ft}^2} = 261 \text{ lb/acre}$$

Using inexpensive clover:

$$\begin{aligned} & [(\$2.18/1000 \text{ ft}^2 \times 1.1) + (\$12.74/1000 \text{ ft}^2 \times 1.441) + \\ & (\$3.66 \times 1.1)] \times \frac{43,560 \text{ ft}^2/\text{acre}}{1000 \text{ ft}^2} = \$1079/\text{acre} \end{aligned}$$

Using expensive crown vetch seed:

$$\begin{aligned} & [(\$36/1000 \text{ ft}^2 \times 1.1) + (\$12.74/1000 \text{ ft}^2 \times 1.441) + \\ & (\$3.66/1000 \text{ ft}^2 \times 1.1)] \times \frac{43,560 \text{ ft}^2/\text{acre}}{1000 \text{ ft}^2} = \$2700/\text{acre} \end{aligned}$$

Typical seed used is slope mix:

$$[(\$7.50/1000 \text{ ft}^2 \times 1.1) + (\$12.74/1000 \text{ ft}^2 \times 1.441) + (\$3.66/1000 \text{ ft}^2 \times 1.1)] \times \frac{43,560 \text{ ft}^2/\text{acre}}{1000 \text{ ft}^2} = \$1334/\text{acre}$$

Source: R. S. Means, Means Site Work Cost Data 1986, p. 105.

- Re-Seeding of Final Cover

Slope mix, 3 lb/1000 ft²; Push spreader used; coal mining company experienced in revegetation recommended that seed application rate be 1/2 of original rate for re-seeding

$$3 \text{ lb}/1000 \text{ ft}^2 \times \frac{43,560 \text{ ft}^2/\text{acre}}{1000 \text{ ft}^2} = 131 \text{ lb}/\text{acre}$$

Using inexpensive clover:

$$[(\$2.18/1000 \text{ ft}^2 \times 0.5 \times 1.1) + (\$12.74/1000 \text{ ft}^2 \times 1.441) + (\$3.66/1000 \text{ ft}^2 \times 1.1)] \times \frac{43560 \text{ ft}^2/\text{acre}}{1000 \text{ ft}^2} = \$1027/\text{acre}$$

Using expensive crown vetch seed:

$$[(\$36/1000 \text{ ft}^2 \times 0.5 \times 1.1) + (\$12.74/1000 \text{ ft}^2 \times 1.441) + (\$3.66/1000 \text{ ft}^2 \times 1.1)] \times \frac{43,560 \text{ ft}^2/\text{acre}}{1000 \text{ ft}^2} = \$1838/\text{acre}$$

Typical seed used is slope mix:

$$[(\$7.50/1000 \text{ ft}^2 \times 0.5 \times 1.1) + (\$12.74/1000 \text{ ft}^2 \times 1.441) + (\$3.66/1000 \text{ ft}^2 \times 1.1)] \times \frac{43,560 \text{ ft}^2/\text{acre}}{1000 \text{ ft}^2} = \$1155/\text{acre}$$

Source: R.S. Means, Means Site Work Cost Data 1986, p. 105.
Coal Company E; July, 1985.

- Fertilizing

fertilizer, 0.2 lb/yd², push spreader:

$$0.2 \text{ lb}/\text{yd}^2 \times \text{yd}^2/9 \text{ ft}^2 \times 43,560 \text{ ft}^2/\text{acre} = 968 \text{ lb}/\text{acre}$$

$$\$0.06/\text{yd}^2 \times \text{yd}^2/9 \text{ ft}^2 \times 43,560 \text{ ft}^2/\text{acre} = \$290/\text{acre}$$

Source: R.S. Means, Means Site Work Cost Data 1986, p. 103.

- Mulching

Hay, 1" deep, hand spread:

$$\$0.55/\text{yd}^2 \times 4840 \text{ yd}^2/\text{acre} = \$2662/\text{acre}$$

Humus Peat, 1" deep, push spreader:

$$\$0.65/\text{yd}^2 \times 4840 \text{ yd}^2/\text{acre} = \$3146/\text{acre}$$

Typical cost is for humus peat, 1" deep = \$3146/acre

Source: R.S. Means, Means Site Work Cost Data 1986, p. 103.

- Off-Site Borrow

Borrow, handspread, bank measure = \$15.40/yd³

Delivery charge, minimum 14 yd³, 1 hr round trip, add \$2.20/yd³

$$\$15.40/\text{yd}^3 + \$2.20/\text{yd}^3 = \$17.60 \text{ yd}^3$$

Source: R.S. Means, Means Site Work Cost Data 1986, p. 31.

- Hand Grading of Soil

Cost includes labor, overhead and profit = \$2.46/yd²

Source: R. S. Means, Means Site Work Cost Data 1986, p. 39.

- Crushed Stone

Purchase: See Final Cover and Revegetation Chapter --
Crushed Stone

Delivery: See Final Cover and Revegetation Chapter --
Delivery

Spreading: Spread dumped material by hand, no compaction =
\$15.35/yd³

Source: R.S. Means, Means Site Work Cost Data 1986, p. 39.

Compaction: Walk behind vibrating roller, 6" lifts, 3 passes =
\$4.14/yd³

Source: R.S. Means, Means Site Work Cost Data 1986, p. 32.

3.2.4 Rodent Control

- Extermination materials and labor = \$30.00/acre

Source: IR&T, An Analysis of Methods for Ensuring Continuity of Operation for Hazardous Waste Disposal Sites, draft report, p. A-36.

3.2.5 Maintenance of pH at Land Treatment Facilities

- To maintain pH between 6 and 7, a typical application rate is 2.5 tons/acre for initial application plus 0.5 tons/acre every 3 to 4 years.

Ground limestone, 1 lb/yd², tractor spreader = \$4.91/1000 ft²

$$\$4.91/1000 \text{ ft}^2 \times \frac{43,560 \text{ ft}^2/\text{acre}}{1000 \text{ ft}^2} = \$213.88/\text{acre (round to } \$214/\text{acre)}$$

$$1 \text{ lb/yd}^2 = 2.5 \text{ tons/acre}$$

- For supplementary applications at 0.5 tons/acre:

0.5 tons/acre - 2.5 tons/acre = 0.20 or 20% of original materials cost

$$\text{Materials cost} = \$4.00/1000 \text{ ft}^2$$

(material cost x amount of material x 10% O&P) +
(labor rate x 44.1% labor overhead) + (equipment cost x 10% O&P)

$$(\$4.00/1000 \text{ ft}^2 \times 0.20 \times 1.1) + (\$0.22/1000 \text{ ft}^2 \times 1.441) +$$

$$(\$0.17/1000 \text{ ft}^2 \times 1.1) = \$1.38/1000 \text{ ft}^2$$

$$\$1.38/1000 \text{ ft}^2 \times \frac{43,560 \text{ ft}^2/\text{acre}}{1000 \text{ ft}^2} = \$60.29/\text{acre (round to } \$60/\text{acre)}$$

Source: R.S. Means, Means Site Work Cost Data 1986, p. 103.
National Lime Association, Arlington, VA,
703-243-5463; July, 1985.
Vendor G; July, 1985.

CHAPTER 4
INVENTORY AND RESIDUAL MANAGEMENT

4.1 ON-SITE MANAGEMENT OF WASTE INVENTORY AND RESIDUALS

Utility and Material Costs

- Gasoline/Diesel Fuel

\$0.94/gal

Source: Oil and Gas Journal, March 24, 1986.

- Electricity

\$0.05/kwh

Source: Monthly Energy Review, U.S. Dept. of Energy, December 1985.

- No. 2 Fuel Oil

$\$0.849/\text{gal} + 23\% \text{ tax} = \$1.04/\text{gal}$

$\$1.04/\text{gal} \div 0.137 \text{ million BTU/gal} = \$7.62/\text{million BTU}$

- No. 6 Fuel Oil

$\$0.642/\text{gal} + 23\% \text{ tax} = \$0.79/\text{gal}$

$\$0.79/\text{gal} \div 0.153 \text{ million BTU/gal} = \$5.16/\text{million BTU}$

Source: Petroleum Marketing Monthly, U.S. Dept. of Energy, November 1985; and Vogel and Martin, "Hazardous Waste Incineration," Part 4, Chemical Engineering, January 9, 1984, p. 98.

- Natural Gas

$\$4.15/1000 \text{ ft}^3 \div 1.02 \text{ million BTU/ft}^3 = \$4.07/\text{million BTU}$

Source: Monthly Energy Review, U.S. Dept. of Energy, December 1985; and Vogel and Martin, "Hazardous Waste Incineration," Part 4, Chemical Engineering, January 9, 1984, p. 98.

- Water

$\$0.91/100 \text{ ft}^3 \times 1.34 = \$1.22/1000 \text{ gal}$

Source: City of St. Paul Water Department, Industrial user rate.

- Sewer Charge

\$1.50/1000 gal

Source: Vogel and Martin, "Hazardous Waste Incineration," Part 4, Chemical Engineering, January 9, 1984, p. 100; and City of St. Paul Water Department.

- Incinerator Ash Disposal

- Secure Landfill

\$100/ton

Source: Pope-Reid Associates, Inc. hazardous waste landfill computer cost model.

- Sanitary Landfill, use only if ash has been tested and is not hazardous.

\$14.00/ton

Source: C. Johnson, "NSWMA's 1985 Tipping Fee Survey," Waste Age, March 1986, p. 58.

- Hydrated Lime

\$48/ton

Source: Chemical Marketing Reporter, April 7, 1986.

- Solidification Raw Materials

- Cement, per ton of bulk cement delivered

$\$66.65/\text{ton} \div 2000 \text{ lb/ton} =$
\$0.033/lb

Source: R.S. Means, Building Construction Cost Data 1986, p. 366.

- Fly Ash

\$0.016/lb

Source: The RCRA Risk-Cost Analysis Model, Phase III Report, USEPA/OSW, January 13, 1984, p. 6-3.

4.1.1 Impoundment Dewatering

- Solar Evaporation

\$4.50/1000 gal = \$.045/gal

Source: Data For Reviewing Closure and Post-Closure Costs of Hazardous Waste Management Facilities, U.S. EPA, Region VII, PEDCo Environmental and A.T. Kearney, Inc., p. 43.

- Pumping (8,000 GPH)

- Equipment Rental Cost (pump, suction hose, discharge hose)

\$98/wk + 10% subcontractor's profit =
\$107.80/wk ÷ 40 hrs/wk = \$2.70/hr

- Equipment Operating Cost

\$0.46/hr + 10% subcontractor's profit =
\$0.51/hr

Source: R.S. Means, Means Site Work Cost Data 1986, p. 16.

- Labor

\$23.00/hr

- Fill Time

	<u>min.</u>
hook up to tanker	10
fill tanker (6500 gal)	49
unhook, bring in next truck	10
	<u>69</u>

Total: 70 min.

- Unit Cost

$$\frac{(\$2.70/\text{hr} + \$0.51/\text{hr} + \$23.00/\text{hr})(70 \text{ min})}{60 \text{ min/hr}} = \$30.58$$

\$30.58 per 6500 gal truckload = \$4.70/1000 gal

- Pumping (15,000 GPH)

- Equipment Rental Cost (pump, suction hose, discharge hose)

\$126/wk + 10% subcontractor's profit =
\$138.60/wk ÷ 40 hrs/wk = \$3.47/hr

- Equipment Operating Cost

\$1.01/hr + 10% subcontractor's profit =
\$1.11/hr

Source: R.S. Means, Means Site Work Cost Data 1986, p. 16.

- Labor

\$23.00/hr

- Fill Time

	<u>min.</u>
hook up to tanker	10
fill tanker (6500 gal)	26
unhook, bring in next truck	10
	<u>46</u>

Total: 46 min

- Unit Cost

$$\frac{(\$3.47/\text{hr} + \$1.11/\text{hr} + \$23.00/\text{hr})(46 \text{ min})}{60 \text{ min/hr}} = \$21.14$$

\$21.14 per 6500 gal truckload = \$3.25/1000 gal

- Discharge to POTW

\$1.50/1000 gal sewer charge (see Utility and Material Costs)

4.1.2 Impoundment Sludge Removal

Sludge Removal

- Backhoe, Front-End Loader, and Shovel

See Table 4-3 for costs, which include an additional 50% for wet excavation.

Source: R.S. Means, Means Site Work Cost Data 1986, pp. 34-35.

- Dragline

See Table 4-3 for costs, which include an additional 100% for wet excavation using a dragline and 50% for all other equipment.

Source: R.S. Means, Means Site Work Cost Data 1985, pp. 34-35.

- Portable Floating Dredge

Rate charged is based on subcontractor's cost to lease and operate the necessary equipment.

- Equipment Leasing Cost

	<u>\$/month</u>
Dredge	11,300
Piping	2,591
Accessories	1,047
	<u>14,938</u>

Total: \$15,000/mo + 10% subcontractor's profit = \$16,500/mo

$$\frac{(\$16,500/\text{mo})(12 \text{ mo}/\text{yr})}{(80\% \text{ utilization rate})(2080 \text{ hrs}/\text{yr})} = \$118.99/\text{hr}$$

Source: Vendor H - Horizontal Auger Dredge Lease Rate Schedule; 1985.

- Equipment Operating Cost

	<u>\$/hr</u>
Fuel (8 GPH)	9.20
Replacement Parts	1.50
Lubrication	0.75
	<u>11.45</u>

Total: \$11.45/hr + 10% subcontractor's profit = \$12.60/hr

Source: Vendor H - Horizontal Auger Dredge Estimated Operation and Maintenance Cost Data; 1985.

- Labor Cost

	<u>\$/hr</u>
Operator	29.50
Laborer	23.00
Mechanic (used 10% of operating hrs)	<u>3.00</u>
	55.50

Total: \$55.50/hr

Source: R.S. Means, Means Site Work Cost Data 1986, p. 223.

- Hourly Output

$$120 \text{ yd}^3/\text{hr} \times 75\% \text{ efficiency} = 90 \text{ yd}^3/\text{hr}$$

Source: Vendor H - Horizontal Auger Dredge
Information Sheet; 1985.

- Unit Cost

$$\frac{(\$118.99/\text{hr} + \$12.60/\text{hr} + \$55.50/\text{hr})}{90 \text{ yd}^3/\text{hr}} = \$2.09/\text{yd}^3$$

Mobilization/Demobilization of Heavy Equipment

- Means provides data on man-hours needed for the mobilization/demobilization of a limited number of equipment sizes, and the resulting costs. In order to obtain costs for other sizes of equipment, equations were derived which relate the number of man-hours needed for a piece of equipment as a function of equipment size. The equation is in the following form:

$$Y = mX + b, \text{ where}$$

Y = time needed for mobil/demobilization (hrs)

X = equipment capacity (yd^3)

m = slope

b = y-intercept

Values for m and b were derived for each equipment type by solving simultaneous equations using the data in Means Site Work Cost Data 1986, p. 41. The resulting general equation was then used to determine the number of man-hours needed for any equipment size. To calculate the mobilization/demobilization cost, this number of man-hours was multiplied by \$76/hr (Source: R.S. Means, Means Site Work Cost Data 1986, p. xx). This process is illustrated by the following example for backhoe mobilization/demobilization.

- Backhoe

<u>capacity (yd³)</u>	<u>man-hours</u>
3/4	1.86
1 1/2	2.76

Source: R.S. Means, Means Site Work Cost Data 1986, p. 41.

Equations from data:

$$1.86 = m (0.75) + b$$

$$2.76 = m (1.50) + b$$

Solving for m and b results in the following general equation and costs:

$$Y = 1.20X + 0.96$$

<u>Capacity (yd³)</u>	<u>Man-Hours</u>	<u>Cost(\$)</u>
1	2.16	165
2	3.36	255
3 1/2	5.16	390

In this manner, general equations were derived and costs calculated for other equipment types using the data from Means, p. 41. These equations are presented below. Specific costs are listed in Tables 4-3 through 4-5 in Volume I.

- Front-End Loader

$$Y = 0.41X + 0.88$$

- Shovel

$$Y = 1.20X + 0.96$$

- Dragline

$$Y = 1.20X + 0.96$$

- Dozer

$$Y = 2.6 \times 10^{-3}X + 1.015, \text{ where } X = \text{size in H.P.}$$

- Portable Floating Dredge

Dredge must be launched using a truck mounted crane. Three to four man-hours are required for mobilization/demobilization. The additional cost for a 12 ton capacity crane is \$235.

$(3.5 \text{ hrs} \times \$76/\text{hr}) + \$235 = \$501.00$

Total mobilization/demobilization cost: \$500

Source: R.S. Means, Means Site Work Cost Data 1986, pp. xx, 18, 41;
and Vendor H - Horizontal Auger Dredge Launching, Loading and
Off-Loading; 1980.

4.1.3 Impoundment Sludge Stabilization

- Unit Cost Ranges

\$33/ton - \$166/ton

Source: Data For Reviewing Closure and Post-Closure Costs of
Hazardous Waste Management Facilities, U.S. EPA,
Region VII, PEDCo Environmental and A.T. Kearney,
Inc., August 1983, p. 48; updated to April 1986
dollars using ENR 20-cities Construction Cost Index
(Engineering News-Record, April 3, 1986).

\$100/ton

Source: The Hazardous Waste Consultant, Volume 2, Issue 3,
May/June 1984, "Costs for Worker Health and Safety
Add Significantly to Hazardous Waste Cleanup Costs,"
SCS Engineers, p. 1-2; updated to April 1986 dollars
using ENR 20-cities Construction Cost Index
(Engineering News Record, April 3, 1986).

4.1.4 Waste Pile Removal and Loading

- Front-End Loader

\$0.85/yd³ - \$1.54/yd³

Source: R.S. Means, Means Site Work Cost Data 1986, p. 34.

4.1.5 Containerization of Bulk Wastes

- Liquids

Assume it takes 15 minutes per drum to fill, seal, and load
drum

Drum cost

\$65.00 each or \$58.50 in lots of 10 or more

Labor

\$29.50/hr

Equipment rental (drum lift)

\$255/week + 10% subcontractor's profit = \$280.50/week ÷ 40
hr/wk = \$7.00/hr

Equipment operating cost

\$5.00/hr + 10% subcontractor's profit = \$5.50/hr

Total Unit Cost

$$\$58.50/\text{drum} + \frac{\$29.50}{\text{hour}} + \frac{\$7.00}{\text{hour}} + \frac{\$5.50}{\text{hour}} \times \frac{50.25 \text{ hr}}{\text{drum}} = \$69/\text{drum}$$

Source: R.S. Means, Building Construction Cost Data 1986, pp.
11, 12. Vendor I, 1986.

- Solids

Handloading at 2.5 CY/day or

$$\frac{2.5 \text{ CY}}{\text{day}} \times \frac{27 \text{ CF}}{\text{CY}} \times \frac{7.34 \text{ gal}}{\text{CF}} \times \frac{\text{drum}}{55 \text{ gal}} = 9 \text{ drums/day}$$

Labor

\$29.50/hr

Drum cost

\$65/each or \$58.50 each in lots of 10 or more

Total Unit Cost

$$\$58.50/\text{drum} + \frac{\$29.50}{\text{hour}} \times \frac{8 \text{ hr}}{\text{day}} \times \frac{\text{day}}{9 \text{ drums}} = \$84.72/\text{drum}$$

Source: R.S. Means, Means Site Work Cost Data 1986; p. 29
Vendor I, 1986.

4.1.6 Recontainerization of Containerized Wastes

- Forklift Rental Cost

\$420/week + 10% subcontractor's profit = \$462/week ÷ 40 hr/wk
= \$11.55/hr

- Forklift Operating Cost

\$5/hr + 10% subcontractor's profit = \$5.50/hr

- Labor

\$29.50/hr (two people will be needed)

- Salvage Drum Cost

\$129/85 gallon salvage drum

- Assume it takes 20 minutes per drum to lift and place in salvage drum, seal salvage drum and load

- Total Unit Cost

$$\text{\$129/drum} + \frac{\text{\$11.55}}{\text{hour}} + \frac{\text{\$5.50}}{\text{hour}} + 2 \times \frac{\text{\$29.50}}{\text{hour}} \times \frac{20 \text{ min}}{60 \text{ min/hour}} = \text{\$144/drum}$$

4.1.7 Container Loading

- Forklift Rental Cost

$$\begin{aligned} &\text{\$420/wk} + 10\% \text{ subcontractor's profit} = \\ &\text{\$462/wk} \div 40 \text{ hr/wk} = \text{\$11.55/hr} \end{aligned}$$

- Forklift Operating Cost

$$\begin{aligned} &\text{\$5.00/hr} + 10\% \text{ subcontractor's profit} = \\ &\text{\$5.50/hr} \end{aligned}$$

Source: R.S. Means, Means Site Work Cost Data 1986, p. 15.

- Labor

\$29.50/hr

- Unit Cost

$$\frac{(\text{\$11.55/hr} + \text{\$5.50/hr} + \text{\$29.50/hr})}{10 \text{ pallets/hr}} = \text{\$4.66/pallet}$$

4.1.8 Landfill Inventory/Residual Disposal

- Dozer

$$\text{\$3.38/yd}^3 - \text{\$5.58/yd}^3$$

Daily outputs listed in Means were reduced by 50% to account for third-party personnel's unfamiliarity with site and additional time needed to uniformly place wastes within the fill area.

Source: R.S. Means, Means Site Work Cost Data 1986, p. 35-36.

- Front-End Loader

\$2.04/ton - \$2.46/ton

Daily outputs listed in Means were reduced by 50% to account for unfamiliarity with site and additional time needed to uniformly place wastes within the fill area. The daily outputs were converted from cubic yards to tons using the factor 1.089 yd³/ton for containerized wastes.

Source: R.S. Means, Means Site Work Cost Data 1986, p. 34.

4.1.9 Absorption of Free Liquids in Containers

- Absorbent Materials

$$\frac{\$194.40/\text{pallet} \times 40 \text{ lb}/\text{ft}^3}{40 \text{ bags}/\text{pallet} \times 50 \text{ lb}/\text{bag} \times 4 \text{ gal absorbed}/\text{ft}^3} = \$0.97/\text{gal absorbed}$$

Source: Vendor I; 1985.

- Labor

\$23.00/hr, 15 min/drum

- Volumes of Free Liquid

1 inch of liquid = $(3.14)(11 \text{ in})^2(1 \text{ in}) - 231 \text{ in}^3/\text{gal} = 1.65 \text{ gal}$

3 inches of liquid = $(3.14)(11 \text{ in})^2(3 \text{ in}) - 231 \text{ in}^3/\text{gal} = 4.9 \text{ gal}$

6 inches of liquid = $(3.14)(11 \text{ in})^2(6 \text{ in}) - 231 \text{ in}^3/\text{gal} = 9.9 \text{ gal}$

- Unit Cost Ranges

$(1.65 \text{ gal} \times \$0.97/\text{gal absorbed}) + (0.25 \text{ hr} \times \$23.00/\text{hr}) = \$7.35$

$(4.9 \text{ gal} \times \$0.97/\text{gal absorbed}) + (0.25 \text{ hr} \times \$23.00/\text{hr}) = \$10.50$

$(9.9 \text{ gal} \times \$0.97/\text{gal absorbed}) + (0.25 \text{ hr} \times \$23.00/\text{hr}) = \$15.35$

4.1.10 Sludge Dewatering Prior to Landfill Disposal

- Belt Filter Press Capital Cost

\$264,876

- Capital Recovery

10 years @ 15%

$$\frac{(1.15)^{10} \times 0.15 \times 264,876}{(1.15)^{10} - 1} = \$52,777/\text{yr}$$

- Maintenance Costs

\$2,396/yr

Source: Innovative and Alternative Technology Assessment Manual, U.S. EPA, 430/9-78-009, February 1980, pp. A-5, A-199. Updated to 1985 dollars using ENR Construction Cost Index, 1977 = 2577 (p. A-199), April 1986 = 4228.95 (Engineering News-Record, April 3, 1986).

- Power Cost

Equipment Capacity: 16,000 lb dry solids/day

Energy Usage: 13 kWh/ton dry solids

Source: Innovative and Alternative Technology Assessment Manual, U.S. EPA, 430/9-78-009, February 1980, p. A-199.

Annual Power Cost

$$\$0.05/\text{kWh} \times 13 \text{ kWh/ton} \times 8 \text{ tons/day} \times 365 \text{ days/yr} = \$1,898/\text{yr}$$

- Labor Cost

$$\begin{aligned} & \$26.50/\text{hr} \times 1460 \text{ hr/yr} = \\ & \$38,690/\text{yr} \end{aligned}$$

- Total Unit Cost

$$\frac{\$52,777/\text{yr} + \$2,396/\text{yr} + \$1,898/\text{yr} + \$38,690/\text{yr}}{6 \text{ wet ton/dry ton} \times 8 \text{ dry ton/day} \times 365 \text{ day/yr}} = \$5.47/\text{wet ton}$$

(round to \$5.50/wet ton)

4.1.11 Solidification of Bulk Wastes Prior to Landfill Disposal

- Equipment Rental Cost

$$\begin{aligned} & \$775/\text{wk} + 10\% \text{ subcontractor's profit} = \$852.50/\text{wk} \div 40 \text{ hr/wk} \\ & = \$21.31/\text{hr} \end{aligned}$$

- Equipment Operating Cost

$$\$5.85/\text{hr} + 10\% \text{ subcontractor's profit} = \$6.44/\text{hr}$$

Source: R.S. Means, Means Site Work Cost Data 1986, p. 13.

- Labor

$$\$23.00/\text{hr}$$

- Subtotal (Equipment and Labor)

$$\$21.31/\text{hr} + \$6.44/\text{hr} + \$23.00/\text{hr} = \$50.75/\text{hr}$$

- Cement-Based Solidification

- Cement Cost

$$\$66.65/\text{ton}$$

Source: R.S. Means, Means Site Work Cost Data 1986, p. 366.

- Mix ratio, by weight (water : cement : waste)

$$4 : 10 : 10$$

- Mix ratio, by volume (water : cement : waste)

$$\frac{4}{62.4 \text{ lb/ft}^3} : \frac{10}{94 \text{ lb/ft}^3} : \frac{10}{1.2 \times 62.4 \text{ lb/ft}^3} =$$

$$0.064 : 0.106 : 0.134$$

- Percent Volume of Waste

$$\frac{0.134}{0.064 + 0.106 + 0.134} = 0.44$$

- Total Unit Cost

$$\frac{\$50.75/\text{hr} \times 2000 \text{ lb/ton}}{0.44 \times 2 \text{ yd}^3/\text{batch} \times 4 \text{ batch/hr} \times 1.2 \times 62.4 \text{ lb/ft}^3 \times 27 \text{ ft}^3/\text{yd}^3}$$

$$+ \$66.65/\text{ton} = \$80.91/\text{ton of waste (round to \$81/ton)}$$

- Fly Ash-Based Solidification

- Fly Ash Cost

\$0.016/lb

Source: The RCRA Risk-Cost Analysis Model, Phase III Report, USEPA/OSW, January 13, 1984, p. 6-3.

- Mix ratio, by weight (water : fly ash : waste)

4 : 10 : 10

- Mix ratio, by volume (water : fly ash : waste)

$$\frac{4}{62.4 \text{ lb/ft}^3} : \frac{10}{40 \text{ lb/ft}^3} : \frac{10}{1.2 \times 62.4 \text{ lb/ft}^3} =$$

0.064 : 0.250 : 0.134

- Percent volume of waste

$$\frac{0.134}{0.064 + 0.250 + 0.134} = 0.30$$

- Total Unit Cost

$$\frac{\$50.75/\text{hr} \times 2000 \text{ lb/ton}}{0.30 \times 2 \text{ yd}^3/\text{batch} \times 4 \text{ batch/hr} \times 1.2 \times 62.4 \text{ lb/ft}^3 \times 27 \text{ ft}^3/\text{yd}^3}$$

+ \$32/ton = \$52.92/ton of waste (round to \$55/ton)

4.1.12 Leachate/Run-Off Removal

- Equipment Rental Cost (pump, suction hose, discharge hose)

\$98/wk + 10% subcontractor's profit =
\$107.80/wk ÷ 40 hrs/wk = \$2.70/hr

- Equipment Operating Cost

\$0.46/hr + 10% subcontractor's profit =
\$0.51/hr

Source: R.S. Means, Means Site Work Cost Data 1986, p. 16.

- Labor
\$23.00/hr
- Closure Pumping Cost (pump present)
 $\$0.51/\text{hr} + \$23.00/\text{hr} = \$23.51/\text{hr}$ (round to \$24/hr)
- Post-Closure Pumping Cost (pump rental needed)
 $\$2.70/\text{hr} + \$0.51/\text{hr} + \$32.00/\text{hr} = \$26.20/\text{hr}$

4.1.13 Landspreading of Inventory/Residuals

- Liquid Wastes and Sludges
 - Equipment Rental Cost
 $\$2,400/\text{wk} + 10\% \text{ subcontractor's profit} =$
 $\$2,640/\text{wk} \div 40 \text{ hr/wk} = \$66.00/\text{hr}$
 - Equipment Operating Cost

	<u>\$/hr</u>
Fuel (6 GPH)	5.64
Replacement Parts	1.50
Lubrication	0.75
	<u>7.89</u>

Total: $\$7.89/\text{hr} + 10\% \text{ subcontractor's profit} = \$8.68/\text{hr}$

Sources: R.S. Means, Means Site Work Cost Data 1986, p. 12;
Vendor J - Sludge Applicators Specifications, 1982 and
August, 1985.

- Application Rate
110-165 tons/day

Source: Vendor J - Sludge Applicators Specifications, 1982.
Application rates were reduced by 50% to account for
third-party personnel's unfamiliarity with site.

- Labor
\$29.50/hr
- Total Unit Cost
 $\$66.00/\text{hr} + \$8.68/\text{hr} + \$29.50/\text{hr} =$
\$104.18/hr

- Unit Cost Ranges

$$\frac{(\$104.18/\text{hr} \times 8 \text{ hr/day})}{110 \text{ ton/day}} = \$7.58/\text{ton}$$

$$\frac{\$104.18/\text{hr} \times 8 \text{ hr/day}}{165 \text{ ton/day}} = \$5.05/\text{ton}$$

- Average Unit Cost

$$\frac{\$5.05/\text{ton} + \$7.58/\text{ton}}{2} = \$6.32/\text{ton}$$

- Solid Wastes

- Equipment Rental Cost for Spreading

$$\begin{aligned} \$400/\text{wk} + 10\% \text{ subcontractor's profit} &= \\ \$440/\text{wk} \div 40 \text{ hr/wk} &= \$11.00/\text{hr} \end{aligned}$$

- Equipment Operating Cost

$$\begin{aligned} \$4.70/\text{hr} + 10\% \text{ subcontractor's profit} &= \\ \$5.17/\text{hr} \end{aligned}$$

Source: R.S. Means, Means Site Work Cost Data 1986, p. 10.

- Spreading Rate

6.5 tons/hr

- Equipment Rental Cost For Disking

$$\begin{aligned} \$550/\text{wk} + 10\% \text{ subcontractor's profit} &= \$605/\text{wk} \div 40 \text{ hr/wk} = \\ \$15.13/\text{hr} \end{aligned}$$

- Equipment Operating Cost for Disking

$$\$5.25 + 10\% \text{ subcontractor's profit} = \$5.78/\text{hr}$$

Source: R.S. Means, Means Site Work Cost Data 1986, pp. 10, 11.

- Disking Rate

3.5 acres/hr

Source: Vendor K; 1984.

- Typical Application Rate

42 tons of waste spread/disked on 6.5 acres of land

Source: Pope-Reid Associates, Inc. hazardous waste land treatment computer cost model.

- Labor

\$29.50/hr

- Spreading Unit Cost

$$\frac{(\$11.00/\text{hr} + \$5.17/\text{hr} + \$29.50/\text{hr})}{6.5 \text{ ton/hr}} = \$7.03/\text{ton}$$

- Disking Unit Cost

$$\frac{(\$15.13/\text{hr} + \$5.78/\text{hr} + \$29.50/\text{hr}) \times (6.5 \text{ acre})}{42 \text{ ton} \times 3.5 \text{ acre/hr}} = \$2.23/\text{ton}$$

- Total Unit Cost

$$\$7.03/\text{ton} + \$2.23/\text{ton} =$$

\$9.26/ton (round to \$9.25/ton)

- Disking Cost/Acre

$$(\$29.50 + \$15.13/\text{hr} + \$5.78/\text{hr}) \times \frac{\text{hr}}{3.5 \text{ acres}} = \$14.40/\text{acre}$$

- Soil Conditioning

- Ground limestone spread with tractor spreader

$$\$4.91/\text{thousand ft}^2 \times 43.56 \text{ thousand ft}^2/\text{acre} =$$
$$\$213.88/\text{acre} \text{ (round to } \$214/\text{acre)}$$

Source: R.S. Means, Means Site Work Cost Data 1986, p. 103.

4.1.14 Incineration of Inventory/Residuals

- Auxiliary Fuel, Electricity, and Lime Costs

See Utility and Material Costs earlier in this section

- Labor

\$26.50/hr

- Ash Generation Rates

	<u>tons ash/tons waste</u>
Solid wastes	0.19
Slurry wastes	0.11
Liquid wastes	0.03

Source: PRA's engineering judgement based on The RCRA Risk-Cost Analysis Model, Phase III Report Appendices, USEPA/OSW, January 13, 1984, Appendix A.

4.2 OFF-SITE MANAGEMENT OF WASTE INVENTORY AND RESIDUALS

4.2.1 Transportation Prices

- Example Cost (Bulk Solids, 250 miles one-way)

\$4.26/one-way mile

Source: Pope-Reid Associates, Inc. hazardous waste transportation computer cost model, 1986 unit cost.

4.2.2 Landfill Prices

Sources: Survey of Selected Firms in the Commercial Hazardous Waste Management Industry: 1984 Update, U.S. EPA Office of Policy Analysis, prepared by ICF Incorporated, September 30, 1985, p. 3-18; and 1986 price schedule for hazardous waste management services obtained from Vendor L.

4.2.3 Incineration Prices

Sources: Survey of Selected Firms in the Commercial Hazardous Waste Management Industry: 1984 Update, U.S. EPA Office of Policy Analysis, prepared by ICF Incorporated, September 30, 1985, p. 3-18.

4.2.4 Deep Well Injection Prices

Sources: Survey of Selected Firms in the Commercial Hazardous Waste Management Industry: 1984 Update, U.S. EPA Office of Policy Analysis, prepared by ICF Incorporated, September 30, 1985, p. 3-18.

4.2.5 Land Treatment Prices

Sources: Survey of Selected Firms in the Commercial Hazardous Waste Management Industry: 1984 Update, U.S. EPA Office of Policy Analysis prepared by ICF Incorporated, September 30, 1985, p. 3-18; and Hazardous Waste Stream Application Rates for a Land Treatment Facility, U.S. EPA/OSW draft report prepared by E&A Environmental Consultants, Inc., January 16, 1984.

4.2.6 Treatment Prices

Source: PRA's engineering judgement based on Survey of Selected Firms in the Commercial Hazardous Waste Management Industry: 1984 Update, U.S. EPA Office of Policy Analysis, prepared by ICF Incorporated, September 30, 1985, p. 3-18.

CHAPTER 5
EQUIPMENT AND FACILITY DECONTAMINATION

5.1 EQUIPMENT DECONTAMINATION

5.1.1 Heavy Equipment

- Equipment Rental Cost

$$\begin{aligned} & \$105/\text{wk} + 10\% \text{ subcontractor's profit} = \\ & \$115.50/\text{wk} \div 40 \text{ hrs/wk} = \$2.89/\text{hr} \end{aligned}$$

- Equipment Operating Cost

$$\begin{aligned} & \$0.29/\text{hr} + 10\% \text{ subcontractor's profit} = \\ & \$0.32/\text{hr} \end{aligned}$$

Source: R.S. Means, Means Site Work Cost Data 1986, p. 17.

- Labor

$$\$23.00/\text{hr}$$

- Unit Cost

$$\$2.89/\text{hr} + \$0.32/\text{hr} + \$23.00/\text{hr} = \$26.21/\text{hr}$$

- Example Cost

$$\begin{aligned} & 1 \text{ dozer takes 3 hours to decontaminate} \\ & (3 \text{ hrs})(\$26.21/\text{hr}) = \$79 \text{ (rounded to nearest dollar)} \end{aligned}$$

5.1.2 Pumps and Feed Lines

- Static Volume

50 feet of 2" diameter line

$$V = \frac{(1 \text{ in})^2 (3.14) (50 \text{ ft}) / 12 \text{ in/ft}}{231 \text{ in}^3/\text{gal}} = 8.16 \text{ gal}$$

- Flush Volume

$$8.16 \text{ gal} + 50\% = 12.24 \text{ gal/flush}$$

- Procedure

One flush with an alkaline cleaning solution followed by a rinse with water. This procedure is then repeated.

- Total Volume
 $(12.24 \text{ gal/flush})(4 \text{ flushes/line}) = 48.96 \text{ gal/line}$
(round to 50 gal/line)
- Caustic Soda: \$28.00/bag (sufficient for cleaning 1-4 lines)
Source: Chemical Marketing Reporter, March 24, 1986.
- Labor
\$23.00/hr
- Example Cost
2 pumps take 12 hours to decontaminate
 $(12 \text{ hrs})(\$23.00/\text{hr}) + (\$28.00) = \$304$ (rounded to nearest dollar)

5.2 FACILITY DECONTAMINATION

5.2.1 Tanks and Other Facility Structures

- Unit Cost Ranges

Steamcleaning

- Equipment Rental Cost
 $\$130/\text{wk} + 10\% \text{ subcontractor's profit} =$
 $\$143/\text{wk} \div 40 \text{ hrs/wk} = \$3.58/\text{hr}$
- Equipment Operating Cost
 $\$0.75/\text{hr} + 10\% \text{ subcontractor's profit} =$
 $\$0.83/\text{hr}$
Source: R.S. Means, Means Site Work Cost Data 1986, p. 17.
- Cleaning Rate: 50 ft²/hr
Source: PRA's engineering judgement based on data listed in
R.S. Means, Building Construction Cost Data 1986, p. 87 and
Vendor M; August, 1984.
- Labor
\$23.00/hr

- Total Unit Cost

$$\frac{(\$3.58/\text{hr} + \$0.83/\text{hr} + \$23.00/\text{hr})}{50 \text{ ft}^2/\text{hr}} = \$0.55/\text{ft}^2$$

High-Pressure Washing

- Equipment Rental Cost

$$\begin{aligned} \$236/\text{wk} + 10\% \text{ subcontractor's profit} &= \\ \$260/\text{wk} \div 40 \text{ hrs/wk} &= \$6.50/\text{hr} \end{aligned}$$

- Equipment Operating Cost

$$\begin{aligned} \$5.32/\text{hr} + 10\% \text{ subcontractor's profit} &= \\ \$5.85/\text{hr} \end{aligned}$$

Source: R.S. Means, Means Site Work Cost Data 1986, p. 14.

- Cleaning Rate: 40 ft²/hr

Source: PRA's engineering judgement based on information from Vendors N, O, and P; August, 1984.

- Labor

$$\$23.00/\text{hr}$$

- Total Unit Cost

$$\frac{(\$6.50/\text{hr} + \$5.85/\text{hr} + \$23.00/\text{hr})}{40 \text{ ft}^2/\text{hr}} = \$0.88/\text{ft}^2$$

Sandblasting

- Equipment Rental Cost

$$\begin{aligned} \$192/\text{wk} + 10\% \text{ subcontractor's profit} &= \\ \$211/\text{wk} \div 40 \text{ hrs/wk} &= \$5.28/\text{hr} \end{aligned}$$

- Equipment Operating Cost

$$\begin{aligned} \$2.55/\text{hr} + 10\% \text{ subcontractor's profit} &= \\ \$2.81/\text{hr} \end{aligned}$$

Source: R.S. Means, Means Site Work Cost Data 1986, p. 17.

- Cleaning Rate: 50 ft²/hr

Source: PRA's engineering judgment based on data listed in R.S. Means, Building Construction Cost Data 1986, p. 77.

- Labor

\$23.00/hr

- Total Unit Cost

$$\frac{(\$5.28/\text{hr} + \$2.81/\text{hr} + \$23.00/\text{hr})}{50 \text{ ft}^2/\text{hr}} = \$0.62/\text{ft}^2$$

Protective Clothing, Basic

	<u>Cost (\$)</u>
splash suit	6.00
shoe covers	4.60
apron	6.00
gloves	10.50
goggles	6.00
respirator + cartridges	40.90
hard hat	6.00
	<u>80.00</u>

- Total Cost: \$80.00

Source: Vendor I; 1986.

Protective Clothing, Tank Entry

	<u>Cost (\$)</u>
splash suit	6.00
shoe covers	4.60
apron	6.00
gloves	10.50
goggles	6.00
chest style gas mask	190.50
organic vapors/ acid gas canister	21.95
hard hat	6.00
	<u>251.55</u>

- Total Cost: \$252 (rounded)

Source: Vendor I; 1986.

5.2.2 Tanks and Vaults Left in Place

- Unit Cost Ranges

Sand

- Buy and load at pit, loose bank sand
\$3.30/yd³

Delivery

- 1 hr round trip
\$2.47/yd³

Placement

- Hand spread, bank measure
\$15.40/yd³

Source: R.S. Means, Means Site Work Cost Data 1986, p. 31.

Total Cost

- $(\$3.30/\text{yd}^3 + \$2.47/\text{yd}^3 + \$15.40/\text{yd}^3) \div 201.96 \text{ gal}/\text{yd}^3 =$
\$0.10/gal

5.2.3 Tank Removal

- Tank Surface Area

The tank removal unit costs are based on tank surface area. When only tank capacity in gallons is known assumptions must be made to determine the tank surface area. The smallest surface area for a cylindrical tank will be achieved when the width and the height are approximately equal. Typically the height is slightly larger or equal to the diameter of a cylindrical tank. The following example shows how the surface area was calculated for a 500, 1000, 2500, 5000, and 10,000 gallon tank.

Example - Tank Surface Area Calculation for a 500 Gallon Tank

$$500 \text{ gallon} \times \frac{\text{ft}^3}{7.48 \text{ gallons}} = 66.84 \text{ ft}^3 \text{ (volume)}$$

$$\text{Volume} = \frac{\pi}{4} d^2 h$$

$$66.84 \text{ ft}^3 = \frac{\pi}{4} d^2 h$$

$$\frac{66.84 \text{ ft}^3}{\frac{\pi}{4}} = d^2 h$$

$$85.11 \text{ ft}^3 = d^2 h$$

Assuming that $d \approx h$, then d or h can be found by:

$$3 \sqrt{d^2 h} = 3 \sqrt{85.11} = 4.4 \text{ ft}$$

If the tank is assumed to be 4 ft in diameter, then height is:

$$h = \frac{85.11}{d^2} = \frac{85.11}{(4)^2} = 5.32 \text{ or } 5.5 \text{ feet}$$

The surface area of a 500 gallon tank is then found using:

$$\text{Surface area} = 2\pi r^2 + 2\pi rh$$

$$\text{Surface area} = 2\pi (2)^2 + 2\pi (2)(5.5) = 94 \text{ ft}^2$$

• Steel or Fiberglass Tank Removal With a Crane

500 gallons	Laborer \$23/hr x 2 hours	= \$ 46
	Crane (\$23/hr + \$28/hr) x 2 + (\$180.20 x 1.1)	= 300
	Crane mobilization/demobilization	= 200
		<u>\$ 546</u>
1,000 gallons	Laborer \$23/hr x 2 hrs	= \$ 69
	Crane (\$23 + \$28) x 2.5 + (\$180.2 x 1.1)	= 326
	Crane mobilization/demobilization	= 200
		<u>\$ 595</u>
2,500 gallons	Laborer \$23/hr x 4 hrs	= \$ 92
	Crane (\$23 + \$28) x 3 + (\$224.20 x 1.1)	= 399
	Crane mobilization/demobilization	= 200
		<u>\$ 691</u>

5,000 gallons	Laborer \$23/hr x 5 hrs	= \$ 115
	Crane (\$23 + \$28) x 4 + (\$224.20 x 1.1)	= 450
	Crane mobilization/demobilization	= 200
		<u>\$ 765</u>
10,000 gallons	Laborer \$23/hr x 7 hrs	= \$ 161
	Crane (\$23 + \$28) x 5 + (\$257.60 x 1.1)	= 538
	Crane mobilization/demobilization	= 200
		<u>\$ 899</u>

Tank Size (gallons)	Surface Area (ft ²)	Unit Cost \$/ft ²
500	100	5.80
1,000	150	4.00
2,500	275	2.50
5,000	425	1.80
10,000	680	1.32

Source: R.S. Means, Building Construction Cost Data 1986, p. 15.
R.S. Means, Means Site Work Cost Data 1986, p. XV

• Steel Tank Removal By Cutting and Moving With a Crane

15,000 gallons	Labor \$23/hr x 7 hrs	= \$ 161
	Welder \$32.60/hr x 8	= 261
	Crane \$51/hr x 8 + \$390.20 x 1.1	= 837
	Crane Mobilization/Demobilization	= 200
		<u>\$1459</u>
20,000 gallons	Labor \$23/hr x 8 hrs	= \$ 184
	Welder \$32.60/hr x 10	= 326
	Crane \$51/hr x 10 + \$390.20/day x 1.1 x 2 days	= 1368
	Crane Mobilization/Demobilization	= 200
		<u>\$2078</u>
25,000 gallons	Labor \$23/hr x 10 hrs	= \$ 230
	Welder \$32.60/hr x 12 hrs	= 391
	Crane \$51/hr x 12 + \$403.80 x 2 x 1.1	= 1500
	Crane Mobilization/Demobilization	= 200
		<u>\$2321</u>
30,000 gallons	Labor \$23/hr x 12 hrs	= \$ 276
	Welder \$32.60/hr x 16 hrs	= 522
	Crane (\$23/hr + \$28/hr) x 16 hr + \$403.80/day x 1.1 x 2 days	= 1704
	Crane Mobilization/Demobilization	= 200
		<u>\$2702</u>

<u>Tank Size (gallons)</u>	<u>Surface Area (ft²)</u>	<u>Unit Cost \$/SF</u>
15,000	> 700	1.96
20,000	> 700	2.35
25,000	> 700	2.20
30,000	> 700	2.27
	Average	2.20

Source: R.S. Means, Building Construction Cost Data 1986, p. 15
R.S. Means, Means Site Work Cost Data 1986, pp. XV, XX.

- Inground tank (concrete)

Tank demolition with jackhammer attachment on backhoe

Mesh reinforcing \$76/CY

Rod reinforcing \$105/CY

Source: R.S. Means, Means Site Work Cost Data 1986, p. 28.

- Cover Removal

\$150/hr to \$300/hr plus \$200 mobilization/demobilization for the hoisting equipment.

Source: National Construction Estimator 1986, p. 227
PRA Engineering judgement

- Cover Demolition

Concrete vaults with a cast-in-place cover to be removed (demolished) at \$3.70/ft² of cover surface. Concrete slab on grade, 6" thick, rod reinforced.

Source: R.S. Means, Means Site Work Cost Data 1986, p. 28.

5.2.4 Container Rinsing

- Equipment Rental Cost

\$175.00/wk + 10% subcontractor's profit =
\$192.50/wk ÷ 40 hrs/wk = \$4.81/hr

- Equipment Operating Cost

$\$4.49/\text{hr} + 10\% \text{ subcontractor's profit} =$
 $\$4.94/\text{hr}$

Source: R.S. Means, Means Site Work Cost Data 1986, p. 14.

- Labor

$\$23.00/\text{hr}$

- Total Cost

$\$4.81/\text{hr} + \$4.94/\text{hr} + \$23.00/\text{hr} =$
 $\$32.75/\text{hr}$

5.2.5 Incinerator Refractory Removal

- Masonry demolition, brick veneers, soft old mortar

$\$1.60/\text{ft}^2$

- Add 100% for congested spaces and small quantities

- Total Unit Cost

$\$3.20/\text{ft}^2$

Source: R.S. Means, Building Construction Cost Data 1986, p. 24.

CHAPTER 6
DEMOLITION AND EXCAVATION

6.1 PAD OR FOUNDATION DEMOLITION

- Unit Cost Ranges

Demolition with Power Equipment

- Site demolition of a six-inch thick concrete pavement, mesh reinforced

$$\$3.92/\text{yd}^2 \times 6 \text{ yd}^2/\text{yd}^3 = \$23.52/\text{yd}^3 \quad (\text{round to } \$23.50/\text{yd}^3)$$

- Site demolition of seven to 24-inch thick concrete pavement, reinforced

$$\$105/\text{yd}^3$$

Source: R.S. Means, Means Site Work Cost Data 1986, p. 28.

Demolition with Hand-Held Equipment

- Site demolition of a six-inch thick concrete pavement, mesh reinforced

$$\$1.61/\text{ft}^2 \times 9 \text{ ft}^2/\text{yd}^2 \times 6 \text{ yd}^2/\text{yd}^3 = \$86.94/\text{yd}^3 \\ (\text{round to } \$87.00/\text{yd}^3)$$

Source: R.S. Means, Means Site Work Cost Data 1986, p.28.

- Site demolition of mesh reinforced slab on grade

$$\$76.00/\text{yd}^3$$

Source: R.S. Means, Means Site Work Cost Data 1986, p. 29.

Core Drilling

- Core drilling, 4" diameter (plus technician)

$$\$15/\text{inch}$$

Source: R.S. Means, Means Site Work Cost Data 1986, p. 8.

6.2 EXCAVATION OF CONTAMINATED SOILS AND CONTAINMENT SYSTEMS

- Unit Cost Ranges

Backhoe

- Medium soil excavated with backhoe and truck loaded
\$1.67 - \$4.60/yd³
- Soft soil or sand
Deduct 15% from the cost for excavating medium soil
\$1.42 - \$3.91/yd³
- Heavy soil or clay
Add 60% to the cost for excavating medium soil
\$2.67 - \$7.36/yd³

Source: R.S. Means, Means Site Work Cost Data 1986, pp. 34.

Front Shovel

- Medium soil excavated with front shovel and truck loaded
\$1.26 - \$3.33/yd³
- Soft soil or sand
Deduct 15% from the cost for excavating medium soil
\$1.07 - \$2.83/yd³
- Heavy soil or clay
Add 60% to the cost for excavating medium soil
\$2.02 - \$5.33/yd³

Source: R.S. Means, Means Site Work Cost Data 1986, p. 35.

Dozer

- 75 H.P. dozer excavating in common earth, 50-300 ft hauls
\$1.39 - \$10.15/yd³

- 105 H.P. dozer excavating in common earth, 50-300 ft hauls
\$1.17 - \$5.95/yd³
- 200 H.P. dozer excavating in common earth, 50-300 ft hauls
\$0.84 - \$3.81/yd³
- 300 H.P. dozer excavating in common earth, 50-300 ft hauls
\$1.13 - \$2.88/yd³

Source: R.S. Means, Means Site Work Cost Data 1986, pp. 35-36.

Front-End Loader

- Loading dozer-excavated material with front-end loader
\$0.85 - \$1.54

Source: R.S. Means, Means Site Work Cost Data 1986, p. 34.

6.3 OTHER COSTS

6.3.1 Mobilization/Demobilization of Heavy Equipment

See Section 4, "Inventory and Residual Management"

6.3.2 Protective Clothing and Safety Equipment

<u>Item</u>	<u>Cost (\$)</u>
total body coveralls	14.00
gloves	10.50
goggles	6.00
respirator + cartridges	40.90
hard hat	6.00
	<u>77.40</u>

- Total Cost: \$77.00 (rounded)

Source: Vendor I; 1986.

- Surcharge for Handling Contaminated Materials

Range of surcharges for excavation: 74% - 146%

Source: Hazardous Waste Consultant, Volume 2 - Issue 3, May/June 1984, "Costs for Worker Health and Safety Add Significantly to Hazardous Waste Cleanup Costs," SCS Engineers, pp. 1-2.

CHAPTER 7

FINAL COVER AND REVEGETATION

7.1 REGULATORY REQUIREMENTS

Recommended Final Cover Layer Thickness

Clay (on-site or off-site)	=	2 ft
Sand or Gravel	=	1 ft
Topsoil	=	2 ft

Source: PRA's engineering judgment based on U.S. EPA, Evaluating Cover Systems for Solid and Hazardous Waste, SW-867, Sept. 1982.

7.2 UNIT COSTS

7.2.1 Native Soil for Slope and Fill

- Design

Shape of the final cover foundation is a pyramid with a 3 percent slope on each side.

Source: Final cover design from PRA's Facilities Design Tool Computer Cost Model.

- Volume (expressed in yd³)

$$V = 1/2 \text{ } wh(1 - 1/3 \text{ } w)$$

where: V = volume in yd³
w = base width (yd)
l = base length (yd)

$$V = \frac{0.03 \text{ } w^2(1-\frac{w}{3})}{4}$$

- Unit Cost Ranges

Excavation

- Assume native soil from excavation of containment system was not saved so must excavate native soil for slope and fill
- Bulk excavating with dozer to rip up soil

- Assume three possible types of native soil
 - (1) sand and gravel
 - (2) common earth
 - (3) clay
- Dozer only used 75 percent of the time, so dozer unit cost multiplied by 75 percent
- 300 H.P. dozer, 150' haul, sand and gravel
 $\$1.47/\text{yd}^3 \times 0.75 = \$1.10/\text{yd}^3$
- 300 H.P. dozer, 150' haul, common earth
 $\$1.69/\text{yd}^3 \times 0.75 = \$1.27/\text{yd}^3$
- 300 H.P. dozer, 150' haul, clay
 $\$2.71/\text{yd}^3 \times 0.75 = \$2.03/\text{yd}^3$
- 300 H.P. dozer, 300' haul, sand and gravel
 $\$2.88/\text{yd}^3 \times 0.75 = \$2.16/\text{yd}^3$
- 300 H.P. dozer, 300' haul, common earth
 $\$3.31/\text{yd}^3 \times 0.75 = \$2.48/\text{yd}^3$ (typical unit cost)
- 300 H.P. dozer, 300' haul, clay
 $\$5.40/\text{yd}^3 \times 0.75 = \$4.05/\text{yd}^3$

Source: R. S. Means, Means Site Work Cost Data 1986,
p. 36.

Placement and Spreading

- Use grading self-propelled scraper to place, spread, and shape
- 15 yd^3 scraper, 1000' haul, 95 yd^3/hr , includes 1/4 push with dozer $\$2.25/\text{yd}^3$ (typical unit cost)
- 25 yd^3 scraper, 1000' haul, 200 yd^3/hr , includes 1/4 push with dozer $\$1.17/\text{yd}^3$

Source: R. S. Means, Means Site Work Cost Data 1986,
p. 39.

Compaction

- Sheepsfoot roller, 4" lifts, 2 passes
 $\$2.07/\text{yd}^3$

- Sheepsfoot roller, 8" lifts, 2 passes
\$1.04/yd³ (typical unit cost)

Source: R. S. Means, Means Site Work Cost Data 1986,
pp. 31 and 32.

- Compaction Factors for Soil Materials

Native soil for slope and fill	= 25% swell
Topsoil	= 25% swell
Sand	= 10% swell
Gravel	= 5% swell
On-site clay (excavated at facility)	= 25% swell
Off-site clay (purchased clay)	= 40% swell

Source: PRA's engineering judgment based on data listed in
Means Site Work Cost Data 1986, p. 235 and the
Unified Soil Classification System.

7.2.2 On-Site Clay

- Unit Cost Ranges

Excavation

- Clay does not come from an existing stockpile, it has to be excavated
- Bulk excavating with a dozer to rip up clay
- Dozer only used 75 percent of the time, so dozer unit cost multiplied by 75 percent
- 300 H.P. dozer, 150' haul
 $\$2.71/\text{yd}^3 \times 0.75 = \$2.03/\text{yd}^3$
- 300 H.P. dozer, 300' haul
 $\$5.40/\text{yd}^3 \times 0.75 = \$4.05/\text{yd}^3$ (typical unit cost)

Source: R. S. Means, Means Site Work Cost Data 1986,
p. 36.

Placement and Spreading

- Use grading self-propelled scraper to place, spread, and shape

- 15 yd³ scraper, 1000' haul, 95 yd³/hr, includes 1/4 push with dozer
\$2.25/yd³ (typical unit cost)
- 25 yd³ scraper, 1000' haul, 200 yd³/hr, includes 1/4 push with dozer
\$1.17/yd³

Source: R. S. Means, Means Site Work Cost Data 1986, p. 39.

Compaction

- Sheepsfoot roller, 4" lifts, 3 passes
\$2.41/yd³ (typical unit cost)
- Sheepsfoot roller, 8" lifts, 3 passes
\$1.22/yd³

Source: R. S. Means, Means Site Work Cost Data 1986, pp. 31 and 32.

• Testing Compacted Clay

- Moisture content = \$7.50/sample
 - Permeability = \$67.00/sample
 - Proctor compaction = \$124.00/sample
 - Sample collection = \$32.00/sample
- \$230.50/sample = \$230/sample

Source: R.S. Means, Means Site Work Cost Data 1986, p. 9.

7.2.3 Off-Site Clay

• Delivery Costs

<u>Distance</u>	<u>Cost (\$/yd³)</u>
1-mile round trip	\$1.56
2-mile round trip	1.95
3-mile round trip	2.32
4-mile round trip	2.61
5-mile round trip	3.64
10-mile round trip	4.60
20-mile round trip	6.50
50-mile round trip	10.16

Means Site Work 1986 does not list a unit cost for hauling earth materials for distances greater than a 20-mile round trip. Curve fit data for 1-20 mile round trip into an equation where $Y = 1.445 (X)^{0.4985}$ and extrapolated to obtain cost for 50-mile round trip.

Source: R. S. Means, Means Site Work Cost Data 1986, p. 40.

- Unit Cost Ranges

Purchase

- \$4.75/yd³ (typical unit cost)

Source: Robert Snow Means Co.; March 1986.

- Air floated clay from Georgia at \$36/ton and 67-80 ft³/ton

\$36/ton and 67 ft³/ton

$$\frac{\$36/\text{ton}}{67 \text{ ft}^3/\text{ton}} = \$0.54/\text{ft}^3$$

$$\frac{\$0.54/\text{ft}^3}{0.03704} = \$14.58/\text{yd}^3$$

\$36/ton and 80 ft³/ton

$$\frac{\$36/\text{ton}}{80 \text{ ft}^3/\text{ton}} = \$0.45/\text{ft}^3$$

$$\frac{\$0.45/\text{ft}^3}{0.03704} = \$12.15/\text{yd}^3$$

Source: Vendor Q; March 1986.

Delivery

- 4-mile round trip
\$2.61/yd³
- 20-mile round trip
\$6.50/yd³
- 50-mile round trip
\$10.16/yd³ (typical unit cost)

Source: See Delivery Costs

Spreading

- Spread dumped material, no compaction, by dozer
\$1.03/yd³ (typical unit cost)

Source: R. S. Means, Means Site Work Cost Data 1986,
p. 39.

Compaction

- Sheepsfoot roller, 4" lifts, 3 passes
\$2.41/yd³ (typical unit cost)
- Sheepsfoot roller, 8" lifts, 3 passes
\$1.22/yd³

Source: R. S. Means, Means Site Work Cost Data 1986,
pp. 31 and 32.

• Testing Compacted Clay

- Moisture content = \$7.50/sample
 - Permeability = \$67.00/sample
 - Proctor compaction = \$124.00/sample
 - Sample collection = \$32.00/sample
- \$230.50/sample = \$230/sample

Source: R.S. Means, Means Site Work Cost Data 1986, p. 9.

7.2.4 Synthetic Membrane

(1) 30-mil PVC synthetic membrane

<u>Size (yd²)</u>	<u>Purchase (\$/yd²)</u>	<u>Delivery (\$/yd²)</u>	<u>Installation (\$/yd²)</u>
1,210	3.60-4.50	0.09-0.45	-
53,240	1.71	0.09-0.45	0.45

Source: Vendor U; March 1986.

(2) 30-mil PVC synthetic membrane

<u>Size (yd²)</u>	<u>Purchase (\$/yd²)</u>	<u>Delivery (\$/yd²)</u>	<u>Installation (\$/yd²)</u>
1,210	2.70	0.09	0.54
53,240	1.62	-	0.36

Source: Vendor V; March 1986.

(3) Typical unit costs

purchase = \$2.70

assumed a typical size of 4,840 yd² (1 acre)

$$1,210 \text{ yd}^2 = \$2.70$$

$$4,840 \text{ yd}^2 = x$$

$$53,240 \text{ yd}^2 = \$1.62$$

$$\frac{3630}{52030} = \frac{x}{1.08}$$

$$x = \$0.08$$

$$\$2.70 - \$0.08 = \$2.62 \text{ (round to } \$2.60)$$

$$\text{delivery} = \$0.25/\text{yd}^2$$

$$\frac{\$0.45 - \$0.09}{2} = \$0.18 + \$0.09 = \$0.27 \text{ (round to } \$0.25)$$

$$\text{installation} = \$0.50/\text{yd}^2$$

$$1,210 \text{ yd}^2 = \$0.54$$

$$4,840 \text{ yd}^2 = x$$

$$53,240 \text{ yd}^2 = \$0.36$$

$$\frac{3630}{52030} = \frac{x}{0.18}$$

$$x = \$0.01$$

$$\$0.54 - \$0.01 = \$0.53 \text{ (round to } \$0.50)$$

(4) Testing synthetic liner

Assume 25% of the total synthetic liner cost

Source: Vendor Z, January 1986.

7.2.5 Gravel

- Unit Cost Range

Purchase

- Purchase bank run gravel, bank measure, includes loading at the pit
\$3.85/yd³ (typical unit cost)

Source: R. S. Means, Means Site Work Cost Data 1986, p. 31.

Delivery

- 4-mile round trip
\$2.61/yd³ (typical unit cost)
- 20-mile round trip
\$6.50/yd³
- 50-mile round trip
\$10.16/yd³

Source: See Delivery Costs

Spreading

- Spread dumped material, no compaction, by dozer
\$1.03/yd³ (typical unit cost)

Source: R. S. Means, Means Site Work Cost Data 1986,
p. 39.

Compaction

- Sheepsfoot roller, 4" lifts, 3 passes
\$2.41/yd³
- Sheepsfoot roller, 8" lifts, 3 passes
\$1.22/yd³ (typical unit cost)

Source: R. S. Means, Means Site Work Cost Data 1985,
pp. 31 and 32.

7.2.6 Sand

Purchase

- Purchase bank sand, loose, damp, includes loading at the pit
\$5.50/yd³ (typical unit cost)

Source: R. S. Means, Means Site Work Cost Data 1986,
p. 31.

Delivery

- 4-mile round trip
\$2.61/yd³ (typical unit cost)
- 20-mile round trip
\$6.50/yd³

- 50-mile round trip
\$10.16/yd³

Source: See Delivery Costs

Spreading

- Spread dumped material, no compaction, by dozer
\$1.03/yd³ (typical unit cost)

Source: R. S. Means, Means Site Work Cost Data 1986, p. 39.

Compaction

- Riding vibrating roller, 6" lifts, 3 passes
\$1.49/yd³ (typical unit cost)
- Riding vibrating roller, 12" lifts, 3 passes
\$0.74/yd³

Source: R. S. Means, Means Site Work Cost Data 1986, p. 31.

7.2.7 Drainage Tile

- Unit Cost Range

Tile

- Three different types of drainage tile could be used in the final cover
 - (1) PVC
 - (2) Concrete
 - (3) Vitrified clay
- Includes delivery
- PVC drainage tile, 10' lengths, S.D.R. 35, 4" diameter
\$0.45/ft x 1.10 (overhead + profit) = \$0.50/ft (typical unit cost)
- PVC drainage tile, 10' lengths, S.D.R. 35, 6" diameter
\$0.97/ft x 1.10 (overhead + profit) = \$1.07/ft

Source: R. S. Means, Means Site Work Cost Data 1986, p. 66.

- Concrete drainage tile, porous wall concrete underdrain, std. strength, 4" diameter \$1.40/ft x 1.10 (overhead + profit) = \$1.54/ft

- Concrete drainage tile, porous wall concrete underdrain, std. strength, 6" diameter \$1.50/ft x 1.10 (overhead + profit) = \$1.65/ft

Source: R. S. Means, Means Site Work Cost Data 1986, p. 69.

- Vitrified clay drainage tile, extra heavy duty strength, premium joints, 4" diameter \$1.65/ft x 1.10 (overhead + profit) = \$1.82/ft
- Vitrified clay drainage tile, extra heavy duty strength, premium joints, 6" diameter \$2.60/ft x 1.10 (overhead + profit) = \$2.86/ft

Source: R. S. Means, Means Site Work Cost Data 1986, p. 67.

Trenching and Backfilling

- In sandy clay soil
- Add 50 percent for compaction with a vibratory plate
- Chain trencher, 40 H.P. operator riding, 6" wide trench and backfill, 12" deep \$0.37/ft x 1.50 (compaction) = \$0.56/ft (typical cost)
- Chain trencher, 40 H.P. operator riding, 8" wide trench and back-fill, 12" deep \$0.45/ft x 1.50 (compaction) = \$0.68/ft

Source: R. S. Means, Means Site Work Cost Data 1986, pp. 38 and 39.

7.2.8 Geotextile Filter Fabric

(1) 140n filter fabric

Quantity (yd ²)	Material (\$/yd ²)
1,210	0.68
2,420	0.68
4,840	0.68
9,680	0.58
24,700	0.53
53,240	0.44

Source: Vendor R; March 1986.

(2) Trevira 1115 filter fabric

<u>Quantity (yd²)</u>	<u>Material (\$/yd²)</u>	<u>Delivery (\$/yd²)</u>	<u>Installation (\$/yd²)</u>
1,210	0.70	0.05	0.10
2,420	0.67	0.05	0.10
4,840	0.64	0.05	0.10
9,680	0.62	0.05	0.10
24,700	0.58	0.05	0.10
53,240	0.56	0.05	0.10

Source: Vendor S; March 1986.

(3) Trevira 1120 filter fabric

<u>Quantity (yd²)</u>	<u>Material (\$/yd²)</u>	<u>Delivery (\$/yd²)</u>	<u>Installation (\$/yd²)</u>
1,210	0.79	0.05	0.10
2,420	0.76	0.05	0.10
4,840	0.73	0.05	0.10
9,680	0.70	0.05	0.10
24,700	0.66	0.05	0.10
53,240	0.63	0.05	0.10

Source: Vendor S; March 1986.

(4) Propex 4553 filter fabric

<u>Quantity (yd²)</u>	<u>Material and Delivery (\$/yd²)</u>	<u>Material PRA est. (1) (\$/yd²)</u>	<u>Delivery PRA est. (1) (\$/yd²)</u>	<u>Installation (\$/yd²)</u>
1,210	1.00	0.95	0.05	0.08
2,420	0.95	0.90	0.05	0.08
4,840	0.90	0.85	0.05	0.08
9,680	0.85	0.80	0.05	0.08
24,700	0.75	0.70	0.05	0.08
53,240	0.65	0.60	0.05	0.08

(1) PRA assumed a delivery cost of \$0.05/yd²

Source: Vendor T; March 1986.

(5) Propex 4551 filter fabric

Quantity (yd ²)	Material and Delivery (\$/yd ²)	Material PRA est. ⁽¹⁾ (\$/yd ²)	Delivery PRA est. ⁽¹⁾ (\$/yd ²)	Installation (\$/yd ²)
1,210	0.70	0.65	0.05	0.08
2,420	0.65	0.60	0.05	0.08
4,840	0.62	0.57	0.05	0.08
9,680	0.59	0.54	0.05	0.08
24,700	0.55	0.51	0.05	0.08
53,240	0.52	0.47	0.05	0.08

(1) PRA assumed a delivery cost of \$0.05/yd²

Source: Vendor T; March 1986.

(6) Typical unit cost

purchase = \$0.69/yd²

assumed a typical size of 4,840 yd² (1 acre)

$$\frac{\$0.68 + \$0.64 + \$0.73 + \$0.85 + \$0.57}{5} = \$0.69/\text{yd}^2$$

delivery = \$0.05/yd²

installation = \$0.09/yd²

$$\frac{\$0.10 + \$0.10 + \$0.08 + \$0.08}{4} = \$0.09/\text{yd}^2$$

7.2.9 Topsoil

• Unit Cost Ranges

Purchase

- Means Site Work 1986 does not list a unit cost for purchasing topsoil. To update cost used escalation rates for 1984 and 1985 from Engineering News Record (ENR) for sand, gravel, and crushed stone. Used ENR escalation rates for 1984 and 1985. Escalation rate for 1984 = 4.2 percent and for 1985 = 4.3 percent.

- Weed free topsoil, includes loading at pit
 $\$5.50/\text{yd}^3 \times 1.10 \text{ (overhead + profit)} \times 1.085 \text{ (inflation factor)} = \$6.56/\text{yd}^3 \text{ (typical unit cost)}$

Source: R. S. Means, Means Site Work Cost Data 1984,
p. 28 and Engineering News Record, Dec. 19,
1985, p.60.

Delivery

- 4-mile round trip
 $\$2.61/\text{yd}^3 \text{ (typical unit cost)}$
- 20-mile round trip
 $\$6.50/\text{yd}^3$
- 50-mile round trip
 $\$10.16/\text{yd}^3$

Source: See Delivery Costs Section

Spreading

- 200 H.P. dozer, no compaction, spread dumped material
 $\$1.03/\text{yd}^3 \text{ (typical unit cost)}$

Source: R. S. Means, Means Site Work Cost Data 1986,
p. 39.

Compaction

- Sheepsfoot roller, 4" lifts, 3 passes
 $\$2.41/\text{yd}^3$
- Sheepsfoot roller, 8" lifts, 3 passes
 $\$1.22/\text{yd}^3 \text{ (typical unit cost)}$

Source: R. S. Means, Means Site Work Cost Data 1986,
pp. 31 and 32.

7.2.10 Crushed Stone

- Unit Cost

Purchase

- Purchase crushed stone, 1 1/2" to 3/4" size, loose,
includes loading at the pit
 $\$11.55/\text{yd}^3 \text{ (typical unit cost)}$

Source: R. S. Means, Means Site Work Cost Data 1986,
p. 31.

Delivery

- 4-mile round trip
\$2.61/yd³ (typical unit cost)
- 20-mile round trip
\$6.50/yd³
- 50-mile round trip
\$10.16/yd³

Source: See Delivery Costs

Spreading

- Spread dumped material, no compaction, by dozer
\$1.03/yd³ (typical unit cost)

Source: R. S. Means, Means Site Work Cost Data 1986,
p. 39.

Compaction

- Sheepsfoot roller, 4" lifts, 3 passes
\$2.41/yd³
- Sheepsfoot roller, 8" lifts, 3 passes
\$1.22/yd³ (typical unit cost)

Source: R. S. Means, Means Site Work Cost Data 1986,
pp. 31 and 32.

7.2.11 Revegetation

- Unit Cost Ranges

Soil preparation/grading

- Rake topsoil, site material, harley rock rake, ideal conditions \$23/MSF = \$1002/acre (typical unit cost)

Source: R. S. Means, Means Site Work Cost Data 1986,
p. 102.

Seeding

- Seed can be spread using either a tractor spreader or hydraulic spreader

- Means Site Work 1986 includes fertilizer and mulch with the seed cost for hydraulic spreading. Tractor spreading only includes the seed cost. To obtain the hydraulic spreading seeding cost without fertilizer and mulch, subtracted the seed, fertilizer, and mulch cost with overhead and profit from the total unit cost. This difference is the labor cost for hydraulic spreading. Added the labor cost with over head and profit to the tractor spreading seed cost with overhead and profit.

Example for slope mix:

tractor spreader
seed only = $\$7.50/\text{MSF} \times 1.10$ (overhead + profit) =
\$8.25/MSF

hydraulic spreader with seed, fertilizer, + mulch
total cost with overhead
and profit (O+P) = \$32/MSF

seed, fertilizer, + mulch
 $\$20/\text{MSF} \times 1.10$ (O+P) = \$22/MSF

labor + equipment with
O+P = \$10/MSF

hydraulic spreader with seed only
 $\$8.25/\text{MSF} + \$10.00/\text{MSF} = \$18.25/\text{MSF} = \$795/\text{acre}$

Seed	Tractor Spreader (\$/MSF)	Hydraulic Spreader (\$/MSF)
Birds foot trefoil, 0.45#/MSF	20.00	24.07
Common bluegrass, 4#/MSF	11.65	15.14
Baron bluegrass, 4#/MSF	24.00	20.98
White clover, 0.67 #/MSF	9.20	12.90
Ladino clover, 0.67 #/MSF	10.90	13.92
Tall fescue, 5.5 #/MSF	21.00	17.09
Chewing fescue, 5.5 #/MSF	22.00	18.20
Crown vetch, 4 #/MSF	46.00	49.70
Annual rye, 10 #/MSF	18.60	15.25
Fine textured rye, 10 #/MSF	28.00	24.70
Shade mix, 6 #/MSF	24.00	21.36
Slope mix, 6 #/MSF	22.00	18.25
		(\$795/acre)
		(typical unit cost)

Source: R. S. Means, Means Site Work Cost Data 1986, pp. 104 and 105.

Fertilizer

- Tractor spreader, 0.2 #/S.Y.
\$4.03/MSF = \$176/acre (typical unit cost)

Source: R. S. Means, Means Site Work Cost Data 1986,
p. 103.

Mulch

- Assume mulch spread using a tractor spreader
- Means Site Work 1986 does not list a unit cost for tractor spreading straw but lists a cost for spreading with a large power mulcher. Means does list a unit cost for spreading other mulches with a tractor spreader. To estimate the unit cost for spreading oat straw used the materials cost for oat straw and the labor and equipment cost for tractor spreading humus peat and peat moss.

oat straw material

$$\$21.40/\text{MSF} \times 1.10 \text{ (overhead + profit)} = \$23.54/\text{MSF}$$

equipment

$$\text{tractor @ } \$0.17/\text{MSF} \times 1.10 \text{ (overhead + profit)} = \\ \$0.19/\text{MSF}$$

labor

$$\begin{aligned} \text{daily output} &= 700 \text{ MSF} \\ \text{labor cost including overhead + profit} &= \$225.60/ \\ \text{day} \\ \$225.60/\text{day} \div 700 \text{ MSF/day} &= \$0.32/\text{MSF} \end{aligned}$$

oat mulch cost

$$\$23.54/\text{MSF} + \$0.19/\text{MSF} + \$0.32/\text{MSF} = \$1048/\text{ac}$$

7.2.12 Mobilization/Demobilization Costs

<u>Equipment</u>	<u>Cost (\$)</u>
105 H.P. dozer	\$ 98
300 H.P. dozer	135
15 yd ³ self-propelled scraper	195
24 yd ³ self-propelled scraper	320
roller (riding vibrating or sheepsfoot)	98-135
tractor	98-135

Source: R. S. Means, Means Site Work Cost Data 1986, p. 41,
and engineering judgment based on Means Site Work.

CHAPTER 8
CERTIFICATION OF CLOSURE AND POST-CLOSURE

Labor Rates

- Labor rates for personnel involved in closure and how they are determined are presented in the "Labor Categories and Rates" section of this volume.

Time Requirements

- The number of hours and visits needed to perform the closure activities are based on PRA's engineering judgement.

CHAPTER 9
LABOR CATEGORIES AND RATES

9.1 CLOSURE LABOR CATEGORIES AND RATES

Closure Labor Rates, Engineering Firm Personnel

- Example, Consulting Engineer
Typical Base Salary: \$42,000/yr
Fringe Benefits: 25% of base salary
Overhead: 80% of base + fringe
$$\frac{\$42,000/\text{yr} \times 1.25 \times 1.80}{2080 \text{ hr/yr}} = \$45.43/\text{hr}$$

Source: PRA's engineering judgement

Closure Labor Rates, Subcontracted Personnel

- Example, Heavy Equipment Operator
Typical Base Salary: \$33,700/yr; average of light, medium, and heavy equipment operators
Fringe Benefits: 25% of base salary
Subcontractor's Overhead and Profit: 45% of base + fringe
$$\frac{\$33,700/\text{yr} \times 1.25 \times 1.45}{2080 \text{ hr/yr}} = \$29.37/\text{hr}$$

Source: PRA's engineering judgement based on R.S. Means, Building Construction Cost Data 1986, pp. 343-346
- Land Surveying Team

	<u>\$/hr</u>
Chief of Party	28.20
Instrument Man	25.40
Rodman/Chainman	22.80
	<u>76.40</u>

Total: \$75/hr

Source: R.S. Means, Building Construction Cost Data, 1986, pp. viii, 5, 344.

- Attorney
\$100/hr
Source: PRA attorney's judgement

9.2 POST-CLOSURE LABOR RATES

- Example, Field Technician
Typical Base Salary: \$19,000/yr
Fringe Benefits: 25% of base salary
Overhead: 80% of base + fringe
$$\frac{\$19,000/\text{yr} \times 1.25 \times 1.80}{2080 \text{ hr/yr}} = \$20.55/\text{hr}$$
- Example, Laborer
\$15.90/hr (including fringe) + 45% subcontractor's overhead and profit = \$23.06/hr
Source: R.S. Means, Building Construction Cost Data, 1986, p. 344.
- Attorney
\$100/hr
Source: PRA attorney's judgement

All hourly rates rounded to nearest \$0.50.

CHAPTER 10

CLOSURE AND POST-CLOSURE INDIRECT COSTS

Three types of sources, cost engineering texts, construction cost manuals, and EPA cost estimation documents, were consulted to determine the appropriateness of including the fees in capital cost estimates. All of these cost estimation sources recommend including engineering and supervision fees, contractor's fees, and contingency fees in project capital cost analyses. Sources consulted include:

- Plant Design and Economics for Chemical Engineers, 3rd edition, Max S. Peters and Klaus D. Timmerhaus, McGraw-Hill Book Company.
- Perry's Chemical Engineer's Handbook, 5th edition, Robert H. Perry, editor, McGraw-Hill Book Company.
- Process Plant Estimating, Evaluation, and Control, Kenneth M. Guthrie, Craftsman Book Company.
- Building Construction Cost Data 1986, R.S. Means Company, Inc.
- Means Site Work Cost Data 1986, R.S. Means Company, Inc.
- National Construction Estimator, Craftsman Book Company.
- "Estimating Water Treatment Costs", 4 vols., EPA-60012-79-162, U.S. Environmental Protection Agency, August 1979.
- "A Standard Procedure for Analysis of Pollution Control Operations", 2 vols., EPA-60018-79-018, U.S. Environmental Protection Agency, June 1979.

LIST OF LABORATORIES

Following is a list of analytical laboratories from which information was obtained for groundwater and/or soil monitoring unit analytical costs.

1. SERCO Labs, Roseville, MN; (612) 636-7173.
2. Twin City Testing and Engineering Labs, St. Paul, MN; (612) 645-3601.
3. Minnesota Valley Testing Labs, New Ulm, MN; (800) 782-3557.
4. Braun Environmental Laboratories, Minneapolis, MN; (612) 941-5600.
5. ERA Labs, Duluth, MN; (218) 728-4473.
6. Princeton Testing Laboratory, Princeton, NJ; (609) 452-9050.
7. Mead CompuChem; (502) 425-3106.
8. Geotechnical Engineering, Apple Valley, MN; (612) 431-5266.

LIST OF VENDORS

Following is a list of vendors and other companies from which unit cost information was obtained.

- A - E.H. Renner and Sons, Anoka, MN; (612) 427-6100.
- B - Soilmoisture Equipment Corp., Santa Barbara, CA; (805) 964-3525.
- C - Landscape Maintenance, St. Paul, MN; (612) 423-2206.
- D - Seasonal Lawn Care, Bloomington, MN; (612) 888-7877.
- E - Peabody Coal, St. Louis, MO; (314) 342-3400.
- F - Midwest Fence, South St. Paul, MN; (612) 451-2221.
- G - Cutler Magner Stone, Duluth, MN; (218) 722-3981.
- H - National Car Rental (for Mud Cat portable floating dredge); (612) 830-2121.
- I - Lab Safety Supply, Safety Equipment Catalog.
- J - Big Wheels, Inc., Paxton, IL; (800) 637-6740.
- K - Allis-Chalmers Corp., Industrial Tractor Div., Topeka, KS;
(913) 354-8401.
- L - Chemical Waste Management, Inc., Riverdale, IL; (312) 844-8360.
- M - Portable Steam Cleaning, Burnsville, MN; (612) 890-1227.
- N - Aqua-Dyne, Inc.; (713) 681-3581.
- O - Partek Corp.; (713) 644-3636.
- P - Jet-Line Services, Inc.; (617) 843-2829.
- Q - J.M. Huber Co.; (912) 745-4751.
- R - Jay Truax Co., Minneapolis, MN; (612) 781-6845.
- S - ARMCO, Inc., Minneapolis, MN; (612) 522-4331.
- T - Brock-White Co., St. Paul, MN; (612) 647-0950.
- U - Watersaver; (313) 642-2360.

- V - Gaston Container System; (316) 321-5140.
- W - Corbett Associates, Inc., Minneapolis, MN; (612) 566-0817
- X - Johnson Screen Co., New Brighton, MN; (612) 636-3900
- Y - Soil Exploration Co., St. Paul, MN; (612) 645-6446
- Z - Gundle Lining Systems, Houston, TX; (800) 435-2008
- AA - Geotechnical Engineering, Roseville, MN; (612) 636-7744
- BB - Meehan Brothers Nursery, Lake Elmo, MN; (612) 777-4321